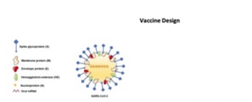
Viral Vaccines SARS-CoV-2 version

Grade 10 and 11

A FACILITATOR'S GUIDE

Mask activity, hand-washing activity, and design a vaccine



*This activity is an adaptation of **Jovian Tsang's** viral vaccine activity (based on a WWZ virus) developed for Let's Talk Science in Ottawa. It was revised and udpated to be focused on the SARS-CoV-2 pandemic and to be done virtually, by the following volunteers: **Amaal Abdi, Abera Surendran, Sue McKee, and Angela Le** for Let's Talk Science in Ottawa*

Thank you for volunteering for Let's Talk Science! The following manual will help guide you through the workshop. Please read this manual before visiting the group you are working with.

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Important Notes

Introduction & Guidelines

- This manual is meant as a guide to help you prepare for your activity. The introduction includes questions that get at the curriculum link/science concept the workshop covers. You are not expected to memorize this manual. It is a guide and we want you to bring your own experiences and your style of teaching into it.
- As a general guideline, do not speak longer than the age of the students at one time.
- Most workshops fit well in a 1-hour time period but some like bridge building or some high school activities are a little longer.
- Practice your introduction and test out the activities beforehand so you can anticipate sections that may take more time or may be difficult for students.
- If you are working with a partner, work out roles and responsibilities before the visit.

Safety

As a Let's Talk Science volunteer, safety must be foremost in our minds during all activities. As STEM role models, volunteers must always also model safe science practices.

Always keep in mind the following precautions:

- Emphasize and demonstrate appropriate safety procedures throughout the presentation.
- Be professional but have fun.
- Keep workspaces clean to avoid tripping hazards.
- Allergens should have been checked before reserving the kit (e.g. allergies to latex).
- **Activity Specific Safety:** n/a

WHMIS

An overview of Canada's Workplace Hazardous Materials Information System (WHMIS) is included in these materials at the end of this manual where needed. No WHMIS sheets are included with this activity.

Overview of the Workshop

Grade Level and Curriculum Learning

Grade 10 *Evaluate the importance of medical and other technological developments related to systems biology, and analyse their societal and ethical implications*

Grade 11 *Evaluate the impact of environmental factors and medical technologies on certain cellular processes that occur in the human body;*

Grade 11 *college describe how different viruses, bacteria, and fungi can affect host organisms, and how those effects are normally treated or prevented*

Grade 12 Science and Public Health Issues: *describe the characteristics according to which a pandemic is classified (e.g., the strain of a virus, its mode of transmission)*

Materials

For each student

2 pieces of tinfoil (put in measurements)
Butter (a small pat of about 2 cm square and 1 cm thick) in tinfoil and a plastic baggie
Small bits of elastics the size of sprinkles in a plastic baggie
Small spoon
1 piece of printer paper (it can be folded in half)
1 small spritzer bottle
1 ½-piece of paper towel
1 of 4 tidbits of information that will help them with their design
Teacher kit:
1 ½ bottle of dish soap
1 small strainer for the teacher
1 pie plate per number of students
4 rolls of double-sided tape

Timing of the Workshop

	Approx. Time (min)	Description
Introduction	5 mins	Introduce yourself, find out what they already know, add in bits to fit with the curriculum learning
Introduction to pandemics and coronaviruses	10-15 mins	Introduction to the material, engaging in some questions and providing some background
COVID-19 virus and handwashing and mask activity	15 mins	Hand washing and mask activity
Developing a vaccine	15-20 mins	Background on vaccines, activity on developing their own COVID-19 vaccine
Wrap up	10 mins	Discussion on their findings

Activity

Note: *The **questions** you might ask are in **bolded blue font**. Some things you might say are in blue font and the possible answers are in square brackets in black font. Actions are in purple font.*

Introduction

Hi everyone! We are Let's Talk Science volunteers. We come to schools and do hands-on activities. I study [simple terms] ________ at the University of Ottawa/Carleton University. I decided to study _____ because [when I was your age I loved… I think it's important to… I'm curious about…].

Today we'll look a little closer at the SARS-CoV-2 which is the name of the virus that causes COVID-19; and you'll be challenged to develop a vaccine.

Ask the teacher if she/he can pick students to answer questions as you ask them. Also, you might not be able to hear the answers so the teacher might have to repeat the answers. If you cannot see the students because the camera doesn't extend to where they can see you on a screen, you'll have to rely on the teacher to know if the students are ready for the next step.

Slide 1

Set the stage: "You are scientists who have come from all over the world to meet at an Emergency World Health Organization conference. There is a current pandemic spreading across the world that affects humans. We have called you all here today because you are the best and brightest scientists from around the world. We want you to develop a vaccine to protect the healthy population of the world. But first, let's review the emergency."

Slide 2

Our objectives for today are:

- Review the emergency situation
- Evaluate vaccine use
- Discuss how vaccines work
- Examine vaccine components
- Design a SARS-CoV-2 vaccine

Slide 3

On March 12, 2020, the World Health Organization (WHO) declared COVID-19 as a pandemic.
What is a pandemic? [worldwide spread of a disease]
What's the difference in a pandemic and an epidemic? [An *epidemic* is defined as "an outbreak of disease that spreads quickly and affects many individuals at the same time." A *pandemic* is a type of *epidemic* (one with greater range and coverage), an outbreak of a disease that occurs over a wide geographic area and affects an exceptionally high proportion of the population. While a *pandemic* may be characterized as a type of *epidemic*, you would not say that an *epidemic* is a type of *pandemic*.]

Slide 4
Does anyone know of any past pandemics we've overcome?

- **Spanish flu:** The Spanish flu occurred in 1918 and is considered the most destructive pandemic in recent history. It infected 500 million people and about 50 million people died. It was caused by an influenza virus, and it is believed to have come from birds. The reason why it is called the Spanish flu is because the first country to start talking about the virus on the news was Spain, which is mostly inhabited by Spanish people.
- **H1N1 or Swine Flu:** occurred during 2009 and was also caused by an Influenza A respiratory virus. Lasted about 19 months and infected an estimated 1.4 billion people with approx. 575,000 deaths worldwide. This virus typically originated in pigs but evolved to infect humans.
- **HIV/AIDS:** Human Immunodeficiency Virus infection and Acquired Immune Deficiency Syndrome where HIV infection interferes with the immune system resulting in increased infection or tumor formation caused by a deficient immune system (AIDS). Is a retrovirus that is transmitted mainly through bodily fluids (except saliva, sweat and tears). Many people are infected with disease today however modern treatment options allow for better prognosis/quality of life.

Slide 5
Let's talk more about coronaviruses.

What are coronaviruses? [Coronaviruses, otherwise known as CoVs, are a family of viruses. All the viruses in this family share things in common with each other. One of the common characteristics that they share is that they cause problems to the respiratory system in both humans and animals.

There are 7 known types of human coronaviruses, four of which are not very severe and simply cause the common cold. The remaining three are very dangerous because they cause severe illness and can even lead to death. We have had epidemics with MERS and SARS and are currently faced with a pandemic due to the novel COVID-19 pandemic. A lot of these viruses come from different species of animals and eventually start infecting other animals and humans as well. We know where the viruses come from, but we don't know exactly how it started and how the animals got them in the first place. Scientists are still learning and figuring that out.

Slide 6
MERS outbreak
The virus was believed to originate in bats but humans contracted it through contact with camels. Human to human transmission however required closed contact with infected individuals was rare to occur outside of hospitals, so the risk globally is considered low. The first reported case was from 2012 and there currently are approx. 2500 cases worldwide (mostly in the Arabia peninsula) and while there aren't any vaccines yet, many are in development.

SARS epidemic
SARS (SARS-CoV) started in 2003. SARS comes from the same family of viruses as COVID-19. SARS and COVID-19 are 80% identical to one another, which means that they are very similar. Many scientists believe that SARS came from some kind of animal (perhaps bats) that

spread to other animals and eventually infected humans. SARS spread to 26 countries including Canada, and infected around 8000 people, and of these, 774 people died.

Slide 7 (slide shows spread over time to April 2020)
Of course, now, we are currently in the midst of the COVID-19 pandemic. The first case was reported in Wuhan, China in December 2019 and quickly spread throughout the world, causing travel restrictions and lockdowns in many countries. It also believed to have originated from bats,

Slide 8
Currently there are over 62 million cases of COVID-19 throughout the world with a death toll of 1,452,430 – and these numbers are increasing each day!! These are huge numbers, especially if we think about the death toll in comparison to some of the other pandemic/epidemics we've faced in the last few years.

Slide 9
Symptoms of COVID-19 include:

- Fevers/chills
- Cough
- Difficulty breathing/shortness of breath
- Sore throat
- Runny nose
- Loss of taste and smell
- Headache/tiredness
- Nausea/abdominal pain

Not all people afflicted with COVID-19 have ALL these symptoms and because some of these are shared with the flu/common cold, it can be hard to know if you have COVID-19. Some COVID-19 patients have no symptoms (called asymptomatic), but they can still spread the disease. It can also take up to 14 days before symptoms develop, meaning an individual can be infected and not be aware for up to 2 weeks.

Slide 10
COVID-19 is spreads by the transmission of droplets or aerosols (suspensions of tiny particles or droplets in the air) from saliva or other bodily fluids, which is why masks and keeping a 2 m distance are very important measures to take to protect yourself from infection.

Other precautions include:

- Limiting non-essential travel
- Quarantine/self-isolating if traveled or feeling sick
- Social distancing (avoiding close contact with people outside of your household/large gatherings)
- Lockdowns (closing down restaurants, stores, schools, etc. in an effort to decrease the amount of cases, especially if there is a big surge of cases or the number of cases is expected to surpass our healthcare capacity)
- Hygiene, including avoiding touching your food or face and washing your hands frequently

Let's see how well hand washing and masks work.

Slide 11
Before we do the handwashing activity, here we have a diagram on the two different types of viruses – enveloped, where there is a lipid membrane layer surrounding the genetic material of the virus, or non-enveloped where there is only a protein shell surrounding the virus. **Does anybody know which one COVID-19 is?** [enveloped] We are going to make a model of each and test how effective of a measure handwashing would be.

NOTE: the following activity is adapted from the Science Buddies activity (https://www.sciencebuddies.org/stem-activities/show-soap-kills-virus).

Ask the teacher to give each student a kit of materials if they haven't already or to distribute the following materials.

Each student needs: 2 pieces of tin foil, a baggie of 'sprinkles' (small elastic pieces), pat of butter, spoon, dish soap (teacher will squirt this in), at least 6 pieces of double-sided tape (teacher will give this out)

1. First we'll make our virus models. Take your two pieces of tinfoil which should be roughly the same size and make two balls. This is the part that carries the viruses' genetic information in the form of RNA or DNA. We'll talk a bit about DNA and RNA in a short time but basically we don't want virus DNA or RNA in our bodies.

Ask the teacher to give each student 6 pieces of double-sided tape

2. Take a piece of double-sided tape and wrap it tightly around one of the foil balls you made. Do this with 3 or 4 pieces in different places and do the same with the 2nd ball. **What does the double sided tape mimic?** [the protein shell or capsid with surrounds and protects the virus's RNA or DNA.]

Ask the teacher to prepare the bowls of very warm water with soap in them for the students (or the students can do this themselves if permitted)

3. Roll one aluminum ball around in the small bits of elastics and press them gently onto the tape. **What do the sprinkles represent?** [proteins that a virus uses to attach to the outside of its host cell. In a non-enveloped virus, If those proteins are damaged, lost, or destroyed, the virus particle can no longer infect its host.]
4. Take the second aluminum ball and cover with an even layer of butter all around and then roll in the sprinkles and press them gently. **What does the butter represent?** [lipid membrane that envelopes, or surrounds, the capsid of enveloped viruses. The fats in butter are a type of lipid similar to the lipids in virus envelops.]
5. Let's compare the two virus models. **How are they similar or different?** [one has the butter layer and one doesn't] **Looking at our virus models, which do you think represents which?** [butter layer = enveloped virus (COVID-19 is an enveloped virus), just the tape = nonenveloped virus]
6. Now drop both model viruses into the bowl with soapy water and swirl around gently so not to make bubbles, making sure that both models get wet with water from all sides.

Make some observations. **What do you notice? Is there a difference between the two? Why or why not?** [Enveloped virus model (butter) should have lost all its elastics because the soap molecules interact with the butter molecules, which leads to the butter layer being destroyed. The non- some enveloped virus on the other hand should have kept its elastics for a much longer time, although eventually it may have lost of them, too] **What do you think this means in the context of viruses and handwashing?** [Dropping both virus models into soapy water mimicked washing your hands with warm water and soap. Swirling the viruses around in the water is similar to you scrubbing your hands with soap. This means that using soap during hand washing can help make enveloped viruses, like the one that causes COVID-19, non-infectious. Which keeps all of us healthier!]

Get students to clean up. Do not put the elastic bits down the drain. Each student can use the strainer to dump the water in the drain and then discard the elastics and their virus models in the garbage. The teacher can keep the tin pie pans and strainer.

While students are at the sink they could also fill up their spritzer bottle.

Let's check out mask wearing now.

They need a spritzer bottle, a piece of paper towel, and a piece of printer paper. These

1. We'll simulate a sneeze using a small spritzer bottle. Hold your bottle in one hand and paper in another about 30 cm or so apart and spray the bottle on one side of the paper.
2. Make a little square/rectangle with the paper towel. This time put the paper towel in front of the sprayer and spray toward the other side of the paper. **What do you notice?**

(Note: both the two experiments above could be taken further (but you probably won't have time. For example, you could test the washing hands one using cold water and test the mask one using fewer layers of paper towel).

Slide 12

Contact tracing, the process of identifying all people that a COVID-19 patient has come in contact with in the last two weeks, is a very important tool used to limit the spread of COVID-19. It helps to identify who should quarantine/stay home and away from others for 2 weeks to help prevent further spread. But it also is very time consuming to determine

Here's a real-life scenario of contact tracing. A group of 40 people attended a BBQ in a park where there was no distancing, and no masks worn for several hours. Two people later developed covid-19 symptoms and within 6-7 days 27 people had covid-19 and 105 people who had some contact with a person with covid-19 from the BBQ had to quarantine from school and work for 14 days.

Side 13

Why do you think a vaccine might be needed? [Even with measures in place, the numbers and more importantly the death toll is still rising. Wearing a mask all the time, physically distancing, and restricted gatherings, are mainly temporary measures, and a vaccine is more likely to be more permanent control.]

Slide 14
What is a vaccine? [biological and chemical formulations that stimulate immunity to an infectious agent]. Vaccines help protect us against the spread of diseases.

Can you think of any vaccines you've gotten? [DPTP (diphtheria, polio, tetanus, pertussis); MMR (measles, mumps, rubella), smallpox, maybe flu or HPV (human papilloma virus); others].

Slide 15
Vaccines help against the spread of infectious diseases as evidence by their successes in combatting these once well-known diseases.

Slide 16 (this slide has interactive parts to it)
Does anyone know *how* vaccines work? [vaccines train your white blood cells (WBC) to recognize an infectious disease agent (such as a virus or bacteria), then when you are exposed to the real thing your immune system can quickly kill it].

When we get sick there is an exposure period between us and the infectious agent (shown here are representative pictures of viruses and bacteria). Sometimes following exposure we can get sick. If the infectious agent is able to overwhelm our immune system the battle may end in death.

Where do you think a vaccine can be used? Before, during or after exposure?
[A vaccine is used before exposure to the infectious agent. It trains the white blood cells in our body to recognize the infectious agent and kill it. You can think of white blood cells as the hound dogs in our immune system. Sniffing out the bad guys and killing them.]

Slide 17 (this slide is interactive)
When a critical portion of a community is immunized against a contagious disease, most members of the community are protected against that disease because there is little opportunity for an outbreak. Even those who are not eligible for certain vaccines—such as infants, pregnant women, or immunocompromised individuals—get some protection because the spread of contagious disease is contained. This is known as "community immunity."

The principle of community immunity applies to control of a variety of contagious diseases, including influenza, measles, mumps, rotavirus, and pneumococcal disease.
https://www.vaccines.gov/basics/protection/

Slide 18
Let's take a look at vaccine components before we get you developing your vaccines.

Slide 19
Does anyone know the two main parts of every vaccine? [vaccines are made up of 2 ingredients: (1) the infectious agent or a part of it, called the antigen; and (2) an adjuvant, which stimulates the immune system to respond. Adjuvants are chemicals that stimulate the immune system. Think of them like flares that tell the immune system "look over here at this foreign particle! Remember this weird thing!"].

Slide 20

Here the dog represents the white blood cells (WBCs) of the immune system. We want our dog to retrieve a sock (which represents the antigen) and by putting a treat (which represents the adjuvant) inside the sock, we can stimulate the dog to go fetch the sock. That's essentially how the two components work together to illicit the appropriate immune response.

Viruses make us sick by killing our healthy cells or changing how our cells function. When our immune system goes to work to get rid of the virus, we often feel unwell. For example, we often get a fever with a flu and many viruses are not functional with heat.

Slide 21
In the past, killed infectious agents, such as viruses, have been used. Generally this is faster than other methods but there's the risk that not all of the infectious particles are killed, which would be really bad (pretty much injecting live virus into people).

Nowadays, vaccines are made with live-attenuated (weakened) infectious agents or subunits (using a single or several components of the whole). In some ways they are more effective than killed infectious agents, and they are definitely much safer. However they are more time consuming to develop.

Live-attenuated vaccines generally generate better immunity since they are able to replicate and the immune system treats them more like a threat and is more likely to react.

Subunit vaccines are made with antigens that we manufacture, meaning we know exactly what the immune system is targeting, so in that way they are typically very safe.

The H1N1 flu vaccine injection used in 2009 is a killed virus while the nasal spray used a live attenuated virus.
The Measles, Mumps and Rubella Virus Vaccine (MMR) uses three live-attenuated (weakened) versions of the actual dangerous versions.
The Hepatitis B vaccine used in Canada is a subunit vaccine that combines antigen from the surface of the virus and aluminum salts.

More recently, there has been a new type of vaccine developed called nucleic acid vaccines. This is where genetically engineered RNA or DNA enveloped in a lipid bilayer is injected into our bodies where the cellular machinery found in our body produces a protein that safely prompts our immune system to respond. The protein produced is usually a portion of the protein on the virus. If you haven't studied DNA and RNA yet, DNA makes proteins in our cells and those proteins help our cells and systems to function properly.

These are some more commonly used adjuvants: aluminum salts, mineral oil, and lipid nanoparticles (more recently).

Slide 22
If you need this slide use it to give a quick example of how DNA goes to RNA to protein.

Slide 23
We need to develop a vaccine for COVID-19, and so that is why you have all been gathered here at today's conference!

Slide 24 (leave this slide up while they develop their vaccine)
We want you to go back to your labs and create a vaccine candidate that will be effective against COVID-19. You will have 10 minutes to develop your vaccine. The class will decide whose vaccine is the 'best'.

You have a drawing of the SARS-CoV-2 virus and the different types of proteins found on its surface. Your task is to design a vaccine against this virus, targeting one of the protein types. Think carefully of which protein you would like to target and why (TIP: consider what the protein's function is and how accessible it is).

Ideally you will work in a group of 2-4 but each of you has a design sheet and could work independently if you choose.

Note: if the students can work in groups, get them to work in a group of 2-4 to develop the vaccine. If they cannot work in groups they can work on their own but let them know we would usually put them in groups. Remind them to wear their masks while in their group and distance where they can.

Because travel is restricted and each group requires a flight to get to, you can choose to share this information with: only one other group/individual OR the whole class OR not share it.

If you choose to share it with the class, we will post it on a slide for all to see. If you choose to share it with one other group, you will have to figure out how to transmit it to the group without breaking physical distancing rules in the classroom. Once you share it with one group/individual you cannot share it with any other groups.

Let the students use the info on the proteins on the slide. You don't have to go through each one. They can ask you questions if they aren't clear on something.

- **Spike glycoprotein**: attaches to the surface of our cells and allows the viral RNA to enter
- **Nucleocapsid proteins** (N): involved in regulating processes relating to the viral genome and may be involved in the replication cycle of the virus
- **Membrane proteins** (M): generate the shape of the viral envelope and complete the virus assembly
- **Envelope proteins** (E): are necessary for the assembly of the virus

At the end of 10 minutes, we will come together for another conference and each group will present their creations. Vaccine components should be justified and refuted through group discussion.

Slide 25 and 26
Have them present their vaccines and let the class decide if they will be effective given the information on the slide.

- lipid nanoparticles are effective adjuvants!
- mineral oil isn't a good adjuvant

- targeting S protein is effective
- targeting other viral proteins is not a good approach

During the discussion at “the conference”, the students should present the data from their publications to support which vaccine they believe will work best.

Pros for a killed vaccine – Creating a killed infectious agent is relatively quick compared to isolating a subunit from an infectious agent (the process actually includes isolating the gene for the subunit – producing mass amounts of it in an expression system and purifying it). If time is of the essence then one would go with a “killed vaccine” vs a “subunit vaccine”.

Pros for a live-attenuated vaccine – Live attenuated vaccines are able to replicate and because of this, the immune system treats them more as a threat than killed or subunit vaccines. Generally, live-attenuated vaccines are able to generate better immunity than killed or subunit vaccines. Making a live-attenuated version of an infectious agent also takes time (the process includes determining the dangerous components of the infectious agent and introducing mutations into the genome to weaken them).

Pros for a subunit vaccine – Subunit vaccines contain antigens that we manufacture. In this way, we know exactly what the immune system is targeting and because of this, subunit vaccines are usually the safest type of vaccines.

Pros for nucleic acid vaccine – One of the biggest advantages that nucleic acid vaccines provide is how quickly they can be produced. Once a pathogen has been identified, its DNA is sequenced, the nucleic acid vaccine can be developed directly from the sequence. They are also easy to manufacture and so can be less costly to be produce. Additionally, because the vaccine is only for a fragment of the virus, there is no risk of infection.

Wrap-Up
Slide 27
Today’s activity has many parallels to how things actually work in real life.

That is, vaccine development takes a long time (months to years). Labs will work with other labs from around the world to achieve a common research goal (international collaborations are encouraged). However, there are also some labs that insist on not collaborating with other or specifically with certain other labs (lab rivalries).

In the context of saving the human race and getting our lives back to normal, sharing useful information with other is important and essential in driving progress and development.

BONUS: Slide 28
As a last activity, let’s see if you can order the steps we take from the bench (in the lab) to the bedside or clinics. Here we have scientists studying a virus called ‘ICV’ and they develop a vaccine against this virus, which they call “Anti-ICV”. But, there are many steps before the virus can be made available. Here are the steps for vaccine development in random order. Select the right, chronological order that each event would take place in. **Animations in slide reveal step by step the right one**

Does anybody have any questions?

If you have extra time, you can ask if they have any questions about university or being a student or about your research.

Thank you for having us in your class today!

Additional Information

Background Information

For more info: https://virologyj.biomedcentral.com/articles/10.1186/s12985-019-1182-0

More info on contact tracing: https://www.who.int/news-room/feature-stories/detail/tracking-covid-19-contact-tracing-in-the-digital-age#:~:text=contact%20tracing%20is%20the%20process,the%20last%20two%20weeks.

Several different types of potential vaccines for COVID-19 are in development, including:

- *Inactivated or weakened virus vaccines*, which use a form of the virus that has been inactivated or weakened so it doesn't cause disease, but still generates an immune response.
- *Protein-based vaccines*, which use harmless fragments of proteins or protein shells that mimic the COVID-19 virus to safely generate an immune response.
- *Viral vector vaccines*, which use a virus that has been genetically engineered so that it can't cause disease but produces coronavirus proteins to safely generate an immune response.
- *RNA and DNA vaccines*, a cutting-edge approach that uses genetically engineered RNA or DNA to generate a protein that itself safely prompts an immune response.

For more information about all COVID-19 vaccines in development, see this WHO publication, which is being updated regularly.

https://www.fda.gov/consumers/consumer-updates/coronavirus-disease-2019-testing-basics

Antigen tests detect virus proteins; nucleic acid tests detect the viral RNA

Vaccine Design

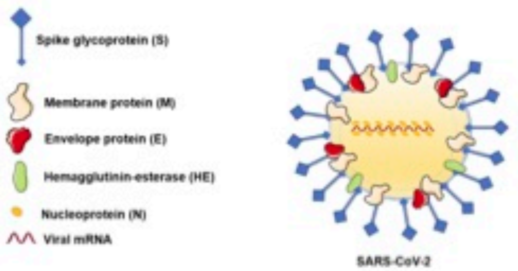

Photo from: **MDPI and ACS Style**; Dehelean, C.A.; et al.. SARS-CoV-2: Repurposed Drugs and Novel Therapeutic Approaches—Insights into Chemical Structure—Biological Activity and Toxicological Screening. *J. Clin. Med.* **2020**, *9*, 2084.